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The Influence of Cattle Grazing and Grass Seeding on Coniferous Regeneration After Shelterwood Cutting in Eastern Oregon

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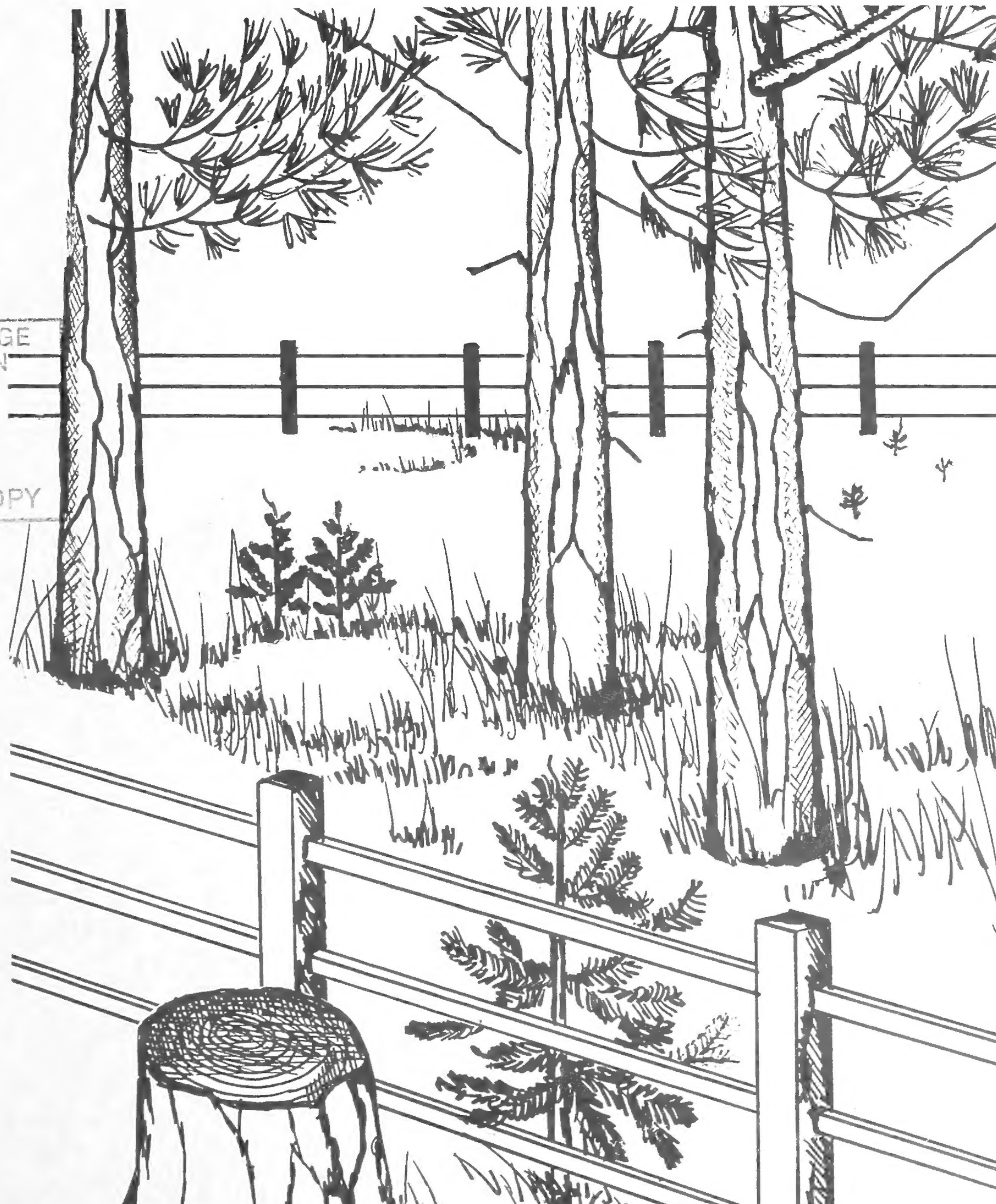

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Abstract

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Natural regeneration was abundant, regardless of grazing and grass seeding treatments, after shelterwood cutting to three overstory densities (27, 73, and 119 square feet of basal area per acre) in mixed conifer stands in the Starkey Experimental Forest and Range in eastern Oregon. After 6 years, the number of tree seedlings ranged from about 3,800 per acre on the low-density plots to 39,000 per acre on the high-density plots and consisted of about 84 percent grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.); 10 percent Douglas-fir (*Pseudotsuga menziesii* var. glauca (Beissn.) Franco); and 6 percent ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), and western larch (*Larix occidentalis* Nutt.). Neither grazing nor seeded grasses decreased seedling establishment, but the grass did retard seedling height growth. The greatest number of seedlings were found on mineral soil seedbeds, but adequate stocking occurred where light to medium amounts of litter and slash were present. A residual overstory of about 30-40 square feet of basal area per acre appears adequate to provide natural regeneration within a 5-year period. Seeding 4 to 5 pounds of less competitive grasses and grazing up to 60 percent of current year's growth were compatible with tree seedling establishment.

Keywords: Shelterwood cutting method, regeneration (natural), grass, forage, grazing, grand fir, *Abies grandis*, Douglas-fir, *Pseudotsuga menziesii* var. *glauca*, Oregon (eastern).

Summary

In 1974, a study began on the Starkey Experimental Forest and Range in eastern Oregon to obtain information about the effects of grass seeding, grazing, and the shelterwood system on natural regeneration and growth, tree seed production, and seedbed condition in old-growth mixed conifer stands. Responses to treatments were evaluated for 6 years after the seed cut.

Study sites were located in a grand fir/big huckleberry (*Abies grandis*/*Vaccinium membranaceum*) plant community that averaged about 183 square feet of basal area per acre; 83 percent was grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), 11 percent Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), and the remainder western larch (*Larix occidentalis* Nutt.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), and lodgepole pine (*Pinus contorta* Dougl. ex Loud.). Average diameter was about 21 inches for grand fir, 18 inches for Douglas-fir, and 23 inches for larch.

Densities of residual overstory tested on whole plots initially were 33, 87, and 137 square feet of basal area per acre. Effects of cattle grazing versus no grazing was tested on split plots, and grass seeding versus no seeding was tested on split-split plots.

Two heavy and four light to medium tree seed crops were produced during the 6 years. The heavy seed crops occurred at the beginning and near the end of the study period. Counts of seed traps begun in 1975 showed that a total of 96,000 sound seeds per acre fell on the low-density plots during the study period compared with 202,000 on the medium-density plots and 220,000 on the high-density plots. These numbers do not include the very heavy seed fall of 1974, the year of the seed cut.

Natural regeneration 6 years after the seed cut ranged from about 3,800 seedlings per acre on the low density plots to 39,000 per acre on the high-density plots, and distribution over the plots was excellent; quadrats ranged from 64 to 97 percent stocked. As expected, quadrats on which nearly all the mineral soil was exposed proved to be the most receptive to seedling establishment at all three overstory densities. Although the greatest number of seedlings were found on mineral soil seedbeds, adequate stocking also occurred where light to medium amounts (up to one-half inch in depth) of litter were present. Complete removal of litter and slash was neither necessary nor desirable for long-term nutrient recycling and other factors. In general, species composition of the natural regeneration was similar to that of the mature stand before logging.

Grazing had no significant effect on seedling establishment nor did it greatly affect height growth. Seeded grasses did not significantly decrease seedling establishment but did significantly reduce height growth. Density of residual overstory also had a significant effect on seedling height growth—growth slowing as density became greater. In grand fir/big huckleberry plant communities, a residual overstory basal area of about 30 to 40 square feet per acre after the seed cut appeared sufficient to provide adequate natural regeneration within a 5-year period. Seeding 4 to 5 pounds of less competitive grasses and grazing up to 60 percent of the current year's growth were compatible with tree seedling establishment. Skillful application of logging and slash disposal techniques is essential to preserve the established reproduction when residual overstory is removed.

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Introduction

The mixed conifer forests of eastern Oregon are truly multiple-use forests.[1] In addition to the value of the timber produced by these forests, domestic livestock and wildlife are also important to the local economy. To successfully manage these multiple-use forests, land managers need information about the effects timber and range management practices have on tree regeneration and understory vegetation. Little information is available about the interacting effects of seeding grasses or grazing on the establishment of tree seedlings and their growth in eastern Oregon; the information that is available generally addresses only planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) after clearcutting (Edgerton 1971).

The shelterwood system is commonly used in mixed conifer stands because it is advantageous for the natural regeneration of true fir species. Information is lacking, however, about the relation of natural seedling establishment to residual stand density after the seed cut, and about the interactions between shelterwood cutting and range management practices. We began in 1974 to investigate the effects of cattle grazing and grass seeding on understory vegetation, and establishment of tree seedlings after shelterwood cutting in mixed conifer stands in the Blue Mountains of eastern Oregon.

Objectives

Objectives of the study were to determine the effects of cattle grazing, grass seeding, and shelterwood cutting and slash disposal on (1) tree seed production and viability; (2) tree seedling recruitment, distribution, and mortality; (3) tree seedling growth; and (4) seedbed condition. Supplemental information was also collected on production of understory vegetation and on soil moisture depletion in treated plot areas. These topics are addressed only to the extent needed to show their influence on study results; detailed information will be reported in subsequent papers.

Study Area

The study sites were located in six old-growth, mixed conifer stands on the Starkey Experimental Forest and Range in the Blue Mountains, about 30 miles southwest of La Grande, Oregon. The sites occur on varied aspects (north to southeast), slopes (5 to 20 percent), and topographic positions (drainage bottom to near ridgetop). Elevations are all about 4,700 feet. Soils on the sites are of the Tolo silt loam series (medial over loamy, mixed, frigid Typic Vitrandepts) or closely related shallower intergrades. They consist of silt-size volcanic ash averaging 29 inches thick over buried soils derived from basaltic and andesitic colluvium.

Total soil depth averaged 36 inches. The ash overburden is silt loam in texture throughout with weak platy structure, mainly in the surface; buried soil horizons are loam to clay loam with moderate to strong subangular blocky to prismatic structure. Few coarse fragments are in the ash layer, but 15 percent or more, by volume, may be in the buried soil. Additional information on the physical and chemical properties of volcanic ash soils is reported by Geist and Strickler (1978).

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[1] The term "mixed conifer forest" in this paper is used in a broad sense to include all stands having two or more species and does not relate to any specific mixed conifer plant community described in classification guides.

The soil and closely related soils of similar volcanic ash size and composition are particularly important for study because they support a large percentage of the commercial forests in this area and geologically related areas of the Western United States and Canada. We would expect study results to apply to volcanic ash soils that have plant communities that are ecologically similar.

Before installation of the study, the overstory basal area averaged about 183 square feet per acre, of which 83 percent was grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), 11 percent Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), 1 percent ponderosa pine and lodgepole pine (*Pinus contorta* Dougl. ex Loud.), and 5 percent western larch (*Larix occidentalis* Nutt.). Average diameter was about 21 inches for grand fir, 18 inches for Douglas-fir, and 23 inches for larch. Site index of grand fir based on Schumacher's (1926) curves indicates a height of 44 feet at age 50.

The study sites are located in a grand fir/big huckleberry plant community (Hall 1973). Principal understory species of this community are: big huckleberry (*Vaccinium membranaceum* Dougl. ex Hook.), heartleaf arnica (*Arnica cordifolia* Hook.), piper anemone (*Anemone piperi* Britt.), sidebells pyrola (*Pyrola secunda* L.), twinflower (*Linnaea borealis* L.), and miterwort (*Mitella stauropetala* Piper).

Methods

The study consisted of three densities of residual overstory, two treatments of grass seeding, and two treatments of cattle grazing, arranged in a completely randomized split-split-plot design replicated two times for a total of six 1-acre whole plots. Densities of residual overstory were tested on the whole plots, cattle grazing treatments on the split plots, and grass seeding treatments on the split-split plots. The three overstory densities were based on leaving 15, 40, and 65 percent of the average basal area of all plots before cutting. This resulted in target residual densities of 27, 73, and 119 square feet of basal area per acre. Actual densities after cutting in 1974 were 33, 87, and 137 square feet per acre (fig. 1). Because of losses from blowdown during the study, overstory basal area in 1981 had decreased to 20, 80, and 124 square feet per acre; species composition of the overstory was about the same as in 1974. The cattle-grazing treatments were none (open to big game but closed to cattle) and open to cattle and big game. The grass-seeding treatments were none and a mixture of orchardgrass (*Dactylis glomerata* L.) (65 percent), big bluegrass (*Poa ampla* Merrill) (22 percent), and timothy (*Phleum pratense* L.) (13 percent) at the rate of 4.6 pounds per acre. Random application of the grazing and seeding treatments to the 1/4-acre subplots resulted in four combinations of grazing and seeding on each whole plot: not grazed-not seeded (O-O), not grazed-seeded (O-S), grazed-not seeded (G-O), and grazed-seeded (G-S) (fig. 2).

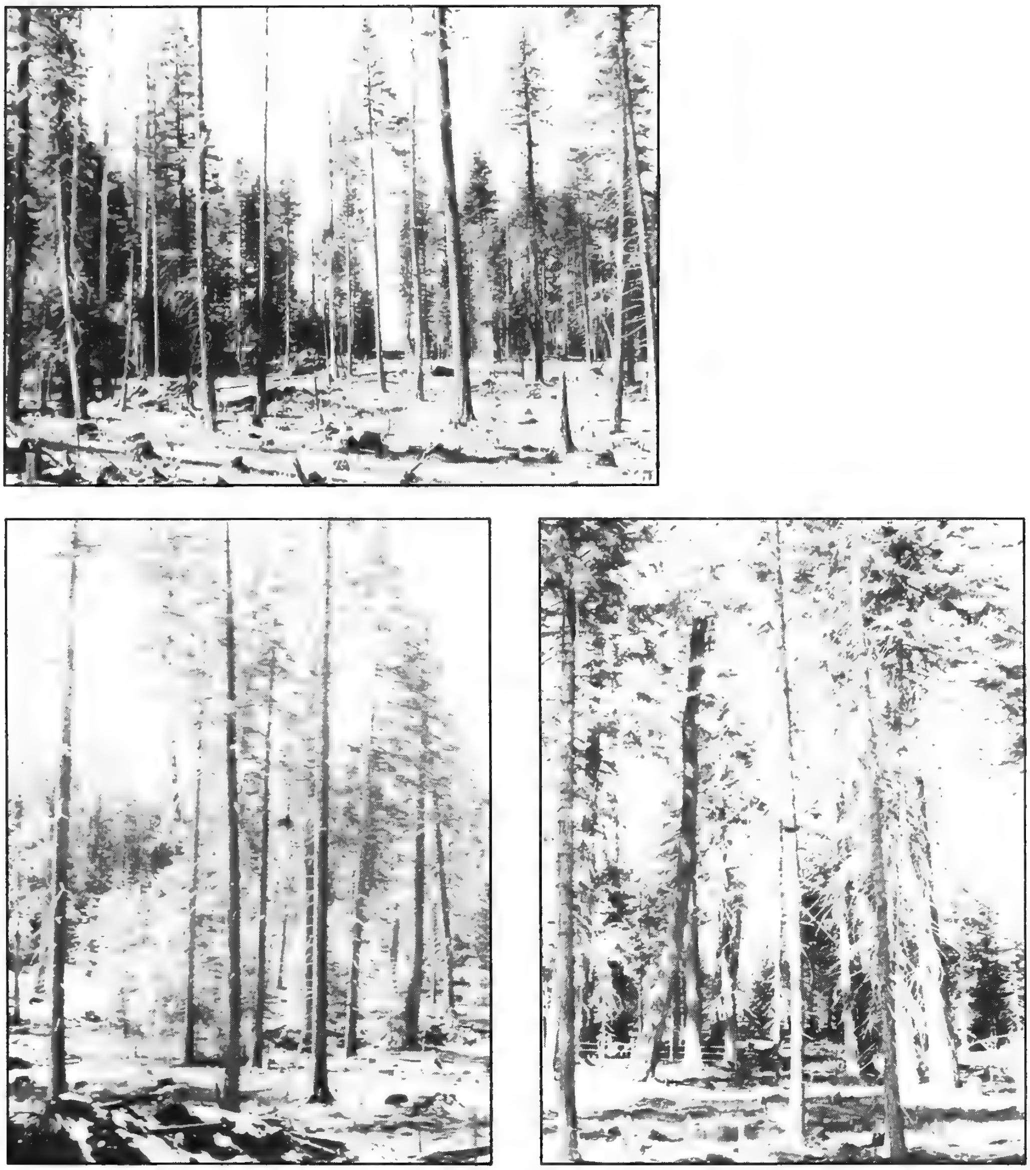

Figure 1—General view of shelterwood plots after the seed cut in 1974: **(A)** 33 square-foot density, **(B)** 87 square-foot density, **(C)** 137-square foot density.

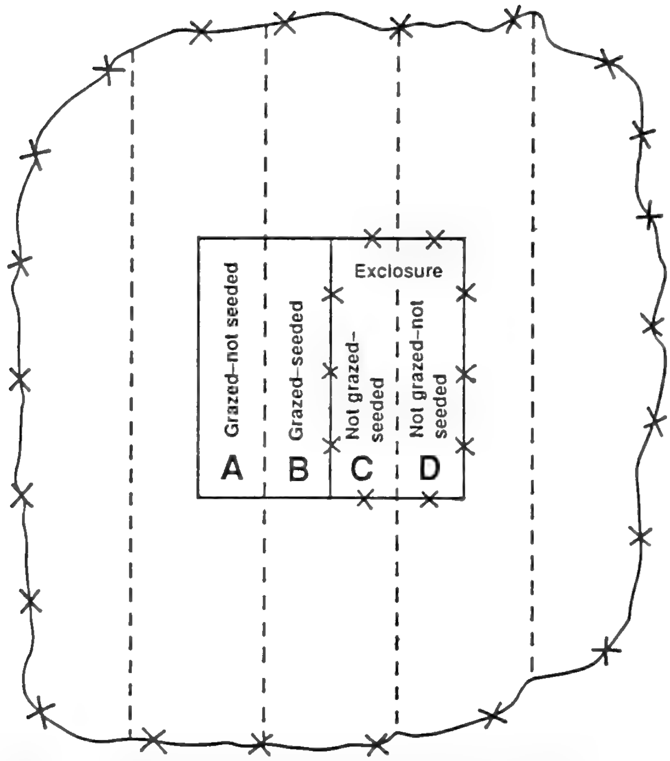

Figure 2—This shelterwood unit depicts split-plot treatments AB (grazed) and CD (not grazed), and split-split plot treatments AD (not seeded) and BC (seeded). An isolation strip surrounds the square, 1-acre whole plot and is fenced (X) to control intensity of livestock grazing. All treatments were assigned at random.

Whole plots were located within small individual stands typically bordered by grassland and were surrounded by a 5-acre buffer zone that was 50 feet or more wide with an overstory density the same as in the plot. Grass was seeded in the buffer zones using the same species and rates as in the subplots. Leave trees were vigorous dominants and codominants. After logging was completed in fall 1974, all slash larger than 1 inch in diameter and longer than 4 feet was mechanically removed from the plots, piled in the buffer strip, and burned. Grass seed was then hand broadcast with cyclone seeders in fall 1974, and fences were constructed to exclude cattle from half of each plot. Cattle grazing was excluded from all plots for one growing season to allow seeded grass to become established and to protect newly germinated tree seedlings.

A herd of cows and calves were used for seasonal grazing beginning in 1976. Cattle were present generally from mid-June to about mid-July or until 55 to 65 percent of the seeded grass (green weight) was consumed (moderate use).

In summer 1975, a grid of 20 permanent, circular 1/2-milacre quadrats was established on each 1/4-acre subplot. Quadrats were systematically spaced at 20-foot intervals on two parallel lines that were 20 feet apart; each line contained 10 quadrats. Annually for 6 years, beginning in the fall of 1975, the total number of seedlings of each species was counted and recorded on each quadrat. Seedlings were identified by year of establishment by placing a color-coded wire pin beside each seedling so that annual mortality of each year's seedlings could be determined. Height of the tallest seedling of each species was also measured annually on each quadrat.

The following environmental factors associated with each quadrat were measured or observed and were recorded at the time of seedling counts: aspect, slope, seedbed condition (mineral soil, litter, slash), and understory vegetation (forbs, shrubs, grasses).

Seedbed and understory vegetation classes proposed by Gordon (1970) were used.

Mineral soil: Bare soil or soil with very minor amounts of organic material on the surface or in mixture.

Litter:
Light: Uniform distribution of needles or small twigs over entire surface but mineral soil visible, or, small patches of medium litter with mineral soil visible between patches.

Medium: Uniform distribution of needles or small twigs to about 1/4-inch depth, or, small patches of heavy litter with mineral soil visible between patches.

Heavy: Needles and small twigs usually 1/4- to 3/4-inch deep, but also deeper, generally in a compact mat, little or no mineral soil visible.

Slash:
Light: Small pieces of slash covering less than 30 percent of surface.

Medium: Any size slash covering 30 to 60 percent of surface.

Heavy: Any size slash covering over 60 percent of surface.

Mineral soil was an exclusive surface type; litter and slash were not exclusive. In other words, if a quadrat was classified as mineral soil, no combinations of litter and slash were allowed. Thus a given quadrat could receive a classification such as mineral soil, or medium litter, or light litter and heavy slash.

The amount of foliar cover was estimated visually. The understory vegetation foliar cover classes used were the following:

Light: covering 5-30 percent of quadrat.

Medium: covering 30-60 percent of quadrat.

Heavy: covering more than 60 percent of quadrat.

Seed fall on each whole plot was sampled annually beginning in 1975 with twenty 1.0-square-foot traps located on a grid of 4 rows; 5 traps were in each row. Seeds were collected each June and were cut to determine empty and sound seed by species.

Soil moisture was monitored by the neutron-scattering method with a depth probe and permanently installed aluminum access tubing. Three tubes per subplot were installed by hand auger in spring 1975 and monitoring followed about monthly thereafter when study plots were accessible. Because the frequency and duration of monitoring was limited, we must report status of observed moisture.

The centimeters of annual soil moisture depletion were computed for a given depth by using the difference in the observed spring maximum and later minimum moisture percentage by volume. This difference multiplied by the associated depth section of monitored soil gave the calculated amount of water depletion from evapotranspiration. The sum of these values for the whole soil was averaged with other tubes in the same treatment subplot to obtain the value for a given replicate.

Split-plot analyses of variance were used to test significance of treatment effects for seedling density, quadrat stocking, and seedling height growth. Tukey's test was used to determine significant differences among treatment means.

Results and Discussion

Tree Seed Production and Dispersal

Large amounts of viable seed fell on the plots in 1974-75, during and after logging and slash disposal, and again in 1978-79 (table 1). Unfortunately, seed traps were not installed until the summer of 1975 so we have no record of the initial seed fall in fall 1974; based on 1975 seedling counts, however, it must have been as high as 500,000 to 1,000,000 sound seeds per acre on the high-density plots. As expected, seed fall generally was greater with increasing stand density. During the 1978-79 seed year, for example, total seed fall increased significantly ($P<0.01$) from 215,622 per acre on the low-density plots (27 square feet per acre) to 488,961 per acre on the high-density plots (119 square feet per acre). About 22-49 percent of the seed was sound.

Grand fir seed was most abundant, comprising about 60-80 percent of the total seed fall during most years. Douglas-fir generally accounted for about 30 percent of the seed fall; ponderosa pine and lodgepole pine seed averaged about 13 percent.

Seed production followed a pattern of 1 year (1974) of high seed yields followed by several years of low yields. The pattern for 1974-80 at Starkey coincides exactly with that in central Oregon (Seidel 1979a). This cyclical pattern of heavy seed production in mixed conifer stands at 3- to 4-year intervals also agrees with the results of Franklin and others (1974) and suggests that a heavy true fir cone crop is likely at least once in any 5-year period. Obviously, a "bumper" crop cannot be expected to coincide with the seed cut as occurred in this study. If, however, the development of competing vegetation follows trends similar to those in this study and seedbed quality is adequate, a delay of several years in obtaining a heavy cone crop is of minor concern in achieving full stocking within 5 years.

Seedling Establishment and Survival

In fall 1975, a great abundance of 1-year-old seedlings was found on all plots as a result of the heavy seed fall in 1974. Seedling numbers ranged from an average of about 15,000 per acre on the low-density plots to more than 82,000 per acre on the high-density plots (table 2 and table 10 [appendix]). Distribution of seedlings over the plots was excellent, with stocking of the 1/2-milacre quadrats ranging from 95 to 100 percent.[2] About 84 percent of the regeneration was grand fir, 10 percent Douglas-fir, 5 percent ponderosa pine and lodgepole pine, and 1 percent western larch.

The greatest number of seedlings were found on those subplots that were not grazed and not seeded with grasses (0-0) (table 3). In 1975, density on these subplots averaged about 63,000 seedlings per acre and decreased to 31,500 by 1980. The large numbers of seedlings on the nongrazed and nonseeded subplots cannot be attributed to lack of grass competition or to no grazing because in 1975 essentially no vegetation of any kind was on any of the subplots and cattle grazing did not begin until June 1976. The greater number of seedlings on the 0-0 subplots was due to one subplot at high density where almost 225,000 seedlings per acre were present in 1975. The other subplots (G-0, G-S, and 0-S) contained fewer seedlings but were also overstocked with 36,000-47,000 seedlings per acre in 1975.

Analysis of the total seedling density for 1975 and 1980 showed no statistical differences in seedling numbers between density levels of residual overstory or grazing and seeding treatments although averages of seedling numbers varied considerably among treatments. This is probably due to the disparity between replications of the same treatment in numbers of seedlings at the high density level. Differences in seedling numbers of the magnitude observed may be real, but the experiment was not statistically sensitive enough to detect them. In contrast, stocking percentages differed little between replicates, and significant differences ($P<0.01$) in percentage of stocked quadrats were found between densities of overstory in both the 1975 and 1980 data. Stocking percentage at the lowest density was significantly less than at the other two densities, but no significant difference was found between the upper two (table 2).

[2] Quadrats were considered stocked if they contained at least one seedling.

Text continues on page 13.

Table 1—Average number of sound and total seeds per acre falling on study plots during seed years from 1975 to 1980 by target density of residual overstory and species

Target density and species[a]	Seed Year 1975-76 Sound	Total	% sound	1976-77 Sound	Total	% sound	1977-78 Sound	Total	% sound
	Number[b]			*Number*[b]			*Number*[b]		
27 ft^2/acre:									
Grand fir	0	16,335 (7,214)	0	5,717 (3,840)	14,702 (5,120)	38.9	5,445 (3,045)	11,979 (9,561)	45.5
Douglas-fir	0	4,356 (3,621)	0	5,445 (3,615)	18,785 (4,676)	29.0	2,178 (2,178)	5,445 (3,920)	40.0
Ponderosa and lodgepole pines	0	27,225 (8,742)	0	0	0		1,089 (1,089)	5,445 (4,792)	20.0
Total	0	47,916 (7,312)	0	11,162 (8,654)	33,487 (7,984)	33.3	8,712 (4,138)	22,869 (9,148)	38.1
73 ft^2/acre:									
Grand fir	0	25,047 (6,415)	0	1,146 (1,146)	1,146 (1,146)	100.0	5,445 (3,267)	14,157 (4,792)	38.5
Douglas fir	0	2,178 (2,178)	0	4,470 (3,820)	28,543 (6,284)	15.7	0	5,445 (3,049)	0
Ponderosa and lodgepole pines	0	4,356 (3,852)	0	0	0	0	2,178 (1,525)	3,267 (1,742)	66.7
Total	0	27,225 (8,319)	0	5,616 (4,312)	29,689 (6,578)	18.9	7,623 (3,920)	22,869 (6,752)	33.3
119 ft^2/acre:									
Grand fir	2,178 (2,178)	49,005 (8,338)	4.4	1,089 (1,089)	7,623 (5,462)	14.3	3,267 (1,742)	20,691 (4,792)	15.8
Douglas-fir	0	8,712 (4,218)	0	1,089 (1,089)	15,246 (5,218)	7.1	2,178 (2,178)	10,890 (5,445)	20.0
Ponderosa and lodgepole pines	0	3,267 (2,561)	0	2,178 (2,178)	4,356 (3,241)	50.0	1,089 (1,089)	2,178 (2,178)	50.0
Total	2,178 (2,178)	60,984 (9,347)	3.6	4,356 (3,879)	27,225 (7,639)	16.0	6,534 (3,267)	33,759 (8,276)	19.4

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.
[b] Standard errors are given in parentheses.

(continued)

Target density and species[a]	Seed Year 1978-79 Sound	Total	% Sound	1979-80 Sound	Total	% Sound
	Number[b]			*Number[b]*		
27 ft^2/acre:						
Grand fir	63,162 (11,108)	163,636 (24,611)	38.6	0	5,445 (2,307)	0
Douglas-fir	14,157 (3,703)	41,956 (11,326)	33.7	0	1,089 (1,089)	0
Ponderosa and lodgepole pines	2,236 (2,236)	10,030 (4,792)	22.3	0	0	0
Total	76,506 (13,068)	215,622 (29,185)	35.5	0	6,534 (2,491)	0
73 ft^2/acre:						
Grand fir	106,722 (28,967)	253,737 (31,799)	42.1	16,335 (4,033)	32,670 (5,990)	50.0
Douglas-fir	16,553 (8,712)	108,900 (17,424)	49.0	2,178 (1,520)	10,890 (4,614)	20.0
Ponderosa and lodgepole pines	8,712 (3,703)	25,047 (7,623)	34.8	1,089 (1,089)	3,267 (1,837)	33.3
Total	168,795 (31,145)	387,684 (37,244)	43.5	19,602 (4,398)	46,827 (8,455)	41.9
119 ft^2/acre:						
Grand fir	153,549 (26,789)	396,396 (51,836)	38.7	3,267 (1,837)	20,691 (5,621)	15.8
Douglas-fir	22,869 (5,881)	60,984 (14,810)	37.5	—	3,267 (1,837)	0
Ponderosa and lodgepole pines	11,979 (5,445)	31,581 (10,672)	37.9	15,246 (3,992)	28,314 (6,896)	53.8
Total	188,397 (30,492)	488,961 (55,103)	33.5	18,513 (4,093)	52,272 (8,134)	35.4

Table 2—Average number of seedlings present per acre (all species) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by target density of residual overstory and year of origin

Target density, year of origin, and percent stocking[a]	1975	1976	1977	1978	1979	1980
	Number of seedlings per acre[b]					
27 ft^2/acre:						
1975	14,838 (1,875)	9,213 (1,211)	6,638 (1,213)	5,163 (906)	3,763 (616)	3,588 (577)
1976		175 (150)	125 (100)	88 (70)	63 (50)	50 (50)
1977			150 (125)	75 (60)	37 (37)	37 (37)
1978				25 (25)	25 (25)	25 (25)
1979					175 (150)	113 (100)
1980						63 (50)
Total	14,838 (1,875)	9,388 (1,289)	6,913 (1,315)	5,351 (989)	4,063 (767)	3,876 (699)
	Percent per 1/2 milacre					
Stocking	95	86	76	72	65	64
	Number of seedlings per acre					
73 ft^2/acre:						
1975	41,863 (5,188)	33,701 (3,212)	29,851 (2,877)	27,264 (2,654)	25,139 (2,742)	23,414 (2,142)
1976		1,463 (334)	1,413 (323)	1,000 (247)	775 (359)	737 (313)
1977			775 (176)	462 (109)	375 (88)	375 (76)
1978				463 (113)	375 (88)	362 (59)
1979					1,938 (402)	1,426 (368)
1980						1,350 (313)
Total	41,863 (5,188)	35,164 (3,517)	32,039 (3,165)	29,189 (2,873)	28,602 (2,856)	27,664 (2,843)
	Percent per 1/2 milacre					
Stocking	100	97	96	96	95	95

See footnotes on next page.

Table 2—Average number of seedlings present per acre (all species) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by target density of residual overstory and year of origin (continued)

Target density, year of origin, and percent stocking[a]	1975	1976	1977	1978	1979	1980
			Number of seedlings per acre[b]			
119 ft^2/acre:						
1975	82,650	66,525	52,463	44,526	38,850	33,250
	(15,784)	(13,413)	(9,876)	(6,189)	(4,102)	(3,206)
1976		1,688	1,526	1,400	1,225	1,213
		(376)	(475)	(376)	(289)	(214)
1977			1,400	1,075	825	738
			(322)	(238)	(201)	(141)
1978				650	463	313
				(153)	(121)	(92)
1979					3,450	2,275
					(789)	(641)
1980						1,225
						(301)
Total	82,650	68,213	55,389	47,651	44,813	39,014
	(15,784)	(14,068)	(10,871)	(7,892)	(6,219)	(4,111)
			Percent per 1/2 milacre			
Stocking	99	99	99	98	98	97

[a] Target density is the average basal area of residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.
[b] Standard errors are given in parentheses.

Table 3—Average number of seedlings present per acre (all species) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by subplot treatment and year of origin

Subplot treatment, year of origin, and percent stocking	1975	1976	1977	1978	1979	1980
			Number of seedlings per acre[a]			
Not grazed, not seeded:						
1975	63,050	53,867	44,084	36,201	31,584	28,000
	(13,476)	(12,254)	(5,332)	(5,142)	(3,269)	(3,218)
1976		1,150	1,000	833	733	716
		(244)	(198)	(313)	(236)	(234)
1977			800	667	667	617
			(212)	(275)	(275)	(238)
1978				267	234	117
				(176)	(143)	(101)
1979					1,533	1,033
					(468)	(313)

See footnote on page 13.

Table 3—Average number of seedlings present per acre (all species) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by subplot treatment and year of origin (continued)

Subplot treatment, year of origin, and percent stocking	Year examined					
	1975	1976	1977	1978	1979	1980
	Number of seedlings per acre[a]					
1980						1,050 (369)
Total	63,050 (13,476)	55,017 (12,777)	45,884 (5,779)	37,968 (5,086)	34,751 (3,896)	31,533 (3,914)
	Percent per 1/2 milacre					
Stocking	97	94	91	88	85	84
	Number of seedlings per acre					
Not grazed, seeded:						
1975	47,100 (6,218)	37,067 (5,203)	28,600 (3,531)	24,033 (2,285)	21,516 (2,089)	19,116 (2,164)
1976		1,483 (409)	1,366 (397)	1,083 (315)	916 (211)	916 (211)
1977			600 (204)	417 (122)	417 (122)	367 (184)
1978				217 (87)	167 (75)	150 (100)
1979					2,633 (417)	1,733 (347)
1980						417 (125)
Total	47,100 (6,218)	38,550 (5,289)	30,566 (4,012)	25,750 (2,714)	25,649 (2,212)	22,699 (2,189)
	Percent per 1/2 milacre					
Stocking	95	91	88	87	84	85
	Number of seedlings per acre					
Grazed, seeded:						
1975	39,300 (5,713)	26,567 (2,812)	22,267 (2,771)	20,650 (2,271)	17,867 (1,867)	16,517 (1,749)
1976		1,000 (377)	967 (342)	767 (218)	617 (171)	617 (171)
1977			1,150 (415)	717 (222)	534 (98)	517 (94)
1978				483 (156)	333 (76)	266 (71)
1979					1,683 (313)	1,216 (212)
1980						950 (187)
Total	39,300 (5,713)	27,567 (2,918)	24,384 (2,943)	22,617 (2,349)	21,034 (1,942)	20,083 (1,876)

Table 3—Average number of seedlings present per acre (all species) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by subplot treatment and year of origin (continued)

Subplot treatment, year of origin, and percent stocking	Year examined					
	1975	1976	1977	1978	1979	1980
	Percent per 1/2 milacre					
Stocking	98	94	89	88	86	85
	Number of seedlings per acre					
Grazed, not seeded:						
1975	36,350 (5,128)	28,417 (3,019)	23,650 (2,841)	21,717 (2,217)	19,367 (1,942)	16,700 (1,842)
1976		800 (289)	750 (217)	633 (249)	483 (167)	416 (151)
1977			550 (176)	350 (102)	183 (84)	183 (84)
1978				550 (176)	417 (111)	400 (126)
1979					1,567 (256)	1,100 (277)
1980						1,100 (289)
Total	36,350 (5,128)	29,217 (3,114)	24,950 (2,817)	23,250 (2,288)	22,017 (2,089)	19,900 (1,876)
	Percent per 1/2 milacre					
Stocking	100	96	92	91	89	88

[a] Standard errors are given in parentheses.

The typical pattern of seedling recruitment and mortality is illustrated in tables 2 and 3. About one-half to three-quarters of the large numbers of seedlings present in 1975 had died in 5 years, with most of the mortality occurring from 1976 through 1978. Mortality rates of grand fir (62 percent) and Douglas-fir (57 percent) were similar (no significant difference) compared to a 42-percent loss of pine seedlings during the 5 years (table 4), which was significantly less than mortality of grand fir or Douglas-fir. Ponderosa pine and lodgepole pine survived as well (no significant difference) in low-density as in high-density plots; in contrast, survival of the firs was significantly less in low-density plots. Higher mortality rates of grand fir in the low-density plots was expected because of the shade tolerance of this species. The reason for the lower mortality rate of all species at medium density is not readily apparent, but the amount of overstory may have protected seedlings from high surface temperatures while still allowing enough sunlight for root growth sufficient to avoid soil drought.

The average seedling mortality was only about 5-6 percent greater in subplots where grass had been seeded than in unseeded subplots (table 4). Grazing also had little effect on seedling mortality. Mortality on grazed and ungrazed subplots was about the same for both grand fir and Douglas-fir and only 6 percent greater for pine on grazed subplots.

Table 4—Percent mortality in 1980 of seedlings present in 1975 by species, grazing, or seeding treatment, and target density of residual overstory

Species and grazing or seeding treatment[a]	Target density of residual overstory[b] 27 square feet per acre	73 square feet per acre	119 square feet per acre	Mean
	Percent			
Grand fir:				
Not grazed	80	44	59	61
Grazed	79	47	59	62
Not seeded	77	43	57	59
Seeded	82	48	61	64
Mean	80	46	59	62
Douglas-fir:				
Not grazed	72	35	63	57
Grazed	78	40	54	57
Not seeded	69	33	63	55
Seeded	81	42	58	60
Mean	75	38	60	57
Ponderosa and lodgepole pines:				
Not grazed	44	19	55	39
Grazed	58	35	41	45
Not seeded	48	21	47	39
Seeded	54	33	49	45
Mean	51	27	48	42

[a] Data for grazed and not grazed treatments are mean values from both seeding treatments; data for seeded and not seeded treatments are mean values from both grazing treatments.

[b] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.

The number of new seedlings established from 1976 to 1980 was sufficient to adequately stock all plots except those at low density. New tree seedlings were found on all plots each year from 1976 through 1980 but did not equal mortality since 1975 (tables 2 and 3). A total of 588 new seedlings per acre were found on the low-density plots from 1976 through 1980 compared to 5,989 per acre on the medium-density plots and 8,413 per acre on the high-density plots (table 5). Of these seedlings, 288 per acre (49 percent) remained in 1980 on low-density plots, 4,250 per acre (71 percent) on medium-density plots, and 5,764 per acre (69 percent) on high-density plots. Based on stocking level curves for east-side grand fir and Douglas-fir (Seidel and Cochran 1981), an area would be considered adequately stocked if it contained about 500 well-distributed seedlings per acre after final removal of the overstory. Assuming a 40-percent loss of seedlings during overstory removal and slash disposal, about 800 established seedlings per acre are needed before overstory removal. Because initial seedling establishment in this study was heavy, additional new seedlings in later years were not needed.

Table 5—Average number of new seedlings per acre (all species) from 1976 to 1980 by target density of residual overstory

Year of origin	Target density of residual overstory[a]: 27 square feet per acre	73 square feet per acre	119 square feet per acre
		Number[b]	
1976	175 (150)	1,463 (334)	1,688 (376)
1977	150 (125)	775 (176)	1,400 (322)
1978	25 (25)	463 (113)	650 (153)
1979	175 (150)	1,938 (402)	3,450 (789)
1980	63 (50)	1,350 (313)	1,225 (301)
Total	588 (450)	5,989 (1,013)	8,413 (2,763)

[a] Target density is the average of the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.

[b] Standard errors are given in parentheses.

These results indicate that a heavy cone crop and seed fall soon after the seed cut offers the best chance of quickly obtaining natural regeneration. Obtaining satisfactory stocking from light cone crops over a number of years, however, is also possible, as this study shows. Seidel (1979a) also found similar results after 5 years in a study of natural regeneration of true fir on the east slopes of the Cascade Range, and Williamson (1973) reported that adequate natural regeneration of Douglas-fir in the Cascades of western Oregon was obtained during years of low seed fall. These results suggest seed cuts need not coincide with heavy seed years if favorable seedbed conditions persist for 3-5 years.

In fall 1980, 6 years after the study began, all subplots were well stocked with seedlings ranging from an average of 3,200 per acre on the low density-not grazed and seeded (0-S) treatment to 60,850 per acre on the high density-not grazed and not seeded (0-0) treatment (fig. 3). The proportion of pine in the regeneration increased from about 6 percent in 1975 to about 11 percent in 1980, primarily because of greater mortality of fir in low-density plots during that time. Lack of regeneration was not a problem in the study, especially at medium and high densities; rather, most sublots are overstocked with seedlings. Even after projected losses of 40 percent during overstory removal and slash disposal, an early precommercial thinning to 400-500 trees per acre would be required to achieve acceptable growth.

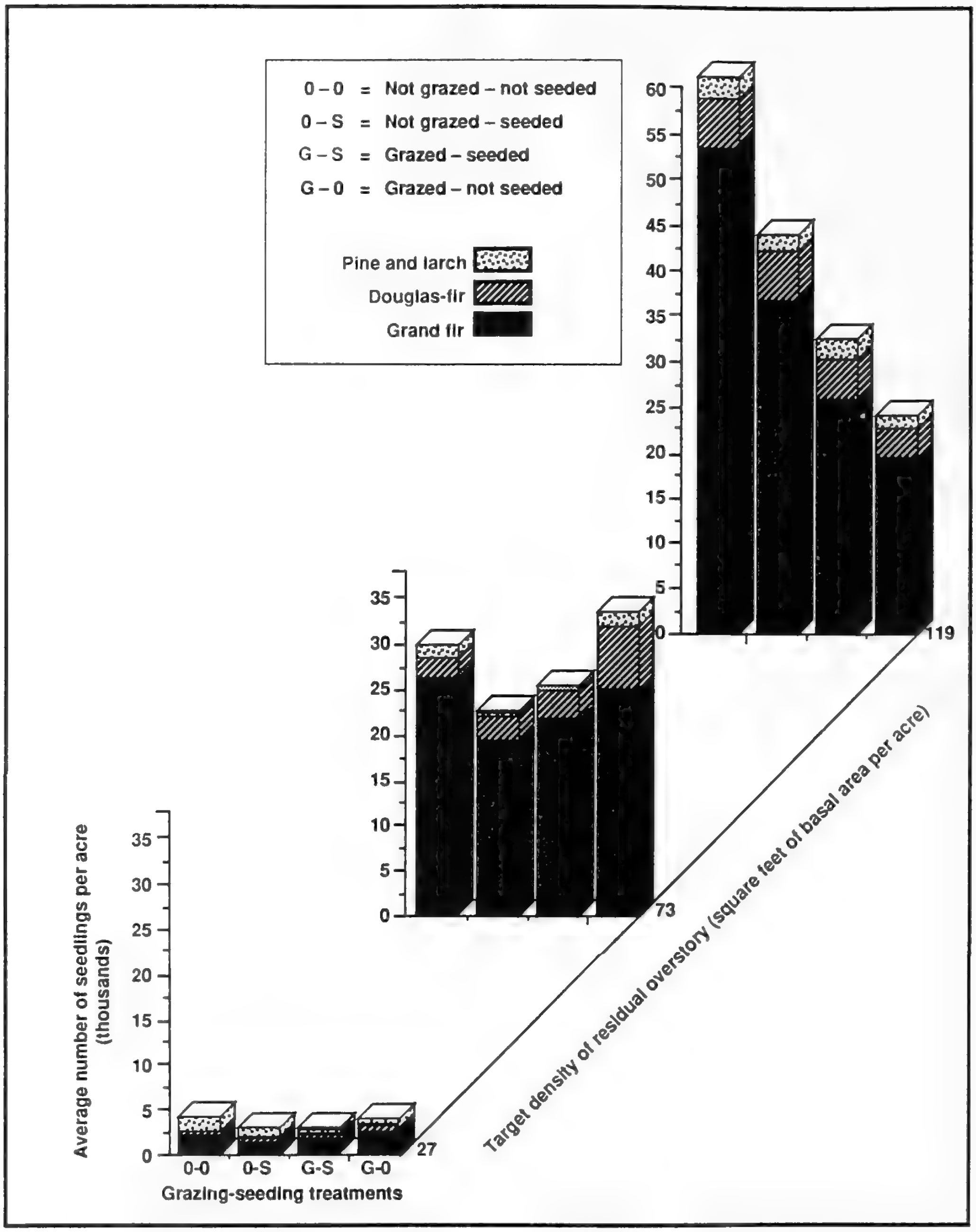

Figure 3—Average number of seedlings per acre (all ages) established in 1980 after the sixth growing season.

Specific soil and site conditions are pertinent to these data and are important to interpretations and extrapolations of the results of this study and similar studies. Volcanic ash materials are very high in water-holding capacity and make a large difference in the water relations of the site. Study results cannot be extrapolated to basalt-derived soils that typically support ponderosa pine in the study region. Water relations in basalt-derived soils are much different from those in ash soils. Also, depending on the kind and degree of surface soil disturbance by logging and slash treatment, the results may not be as applicable to plant communities containing abundant shrubs or rhizomatous grasses and sedges such as pinegrass (*Calamagrostis rubescens* Buckl.) and elk sedge (*Carex geyeri* Boott) that may reestablish or respond vigorously.

Seedling Height Growth

Grand fir and Douglas-fir seedlings grew at about the same rate—the tallest seedlings averaging about 6-9 inches after 6 years (table 11, appendix) while pine seedlings generally grew faster. Pine seedlings also responded to a decrease in overstory density by significantly ($P<0.01$) increased height growth, but the firs showed little difference in height growth between densities (fig. 4). The average height of the tallest pines in the high-density plots (9 inches) was 44 percent less than heights of pines in the low-density plots (16 inches) in 1980 because of the suppressive effect of the additional overstory. A significant difference ($P<0.05$) in height also was found between seedlings growing in grass-seeded versus unseeded subplots for all species in 1980 (fig. 5). After six growing seasons, pine seedlings were 24 percent taller in unseeded subplots, Douglas-firs were 23 percent taller, and grand firs were 19 percent taller.

Grazing during the 1 summer month from 1976 through 1980 did not significantly impact seedling height, although average trends indicated small negative effects (fig. 5). Pine seedlings were 6 percent taller in ungrazed subplots, Douglas-firs were 9 percent taller, and grand firs were 5 percent taller.

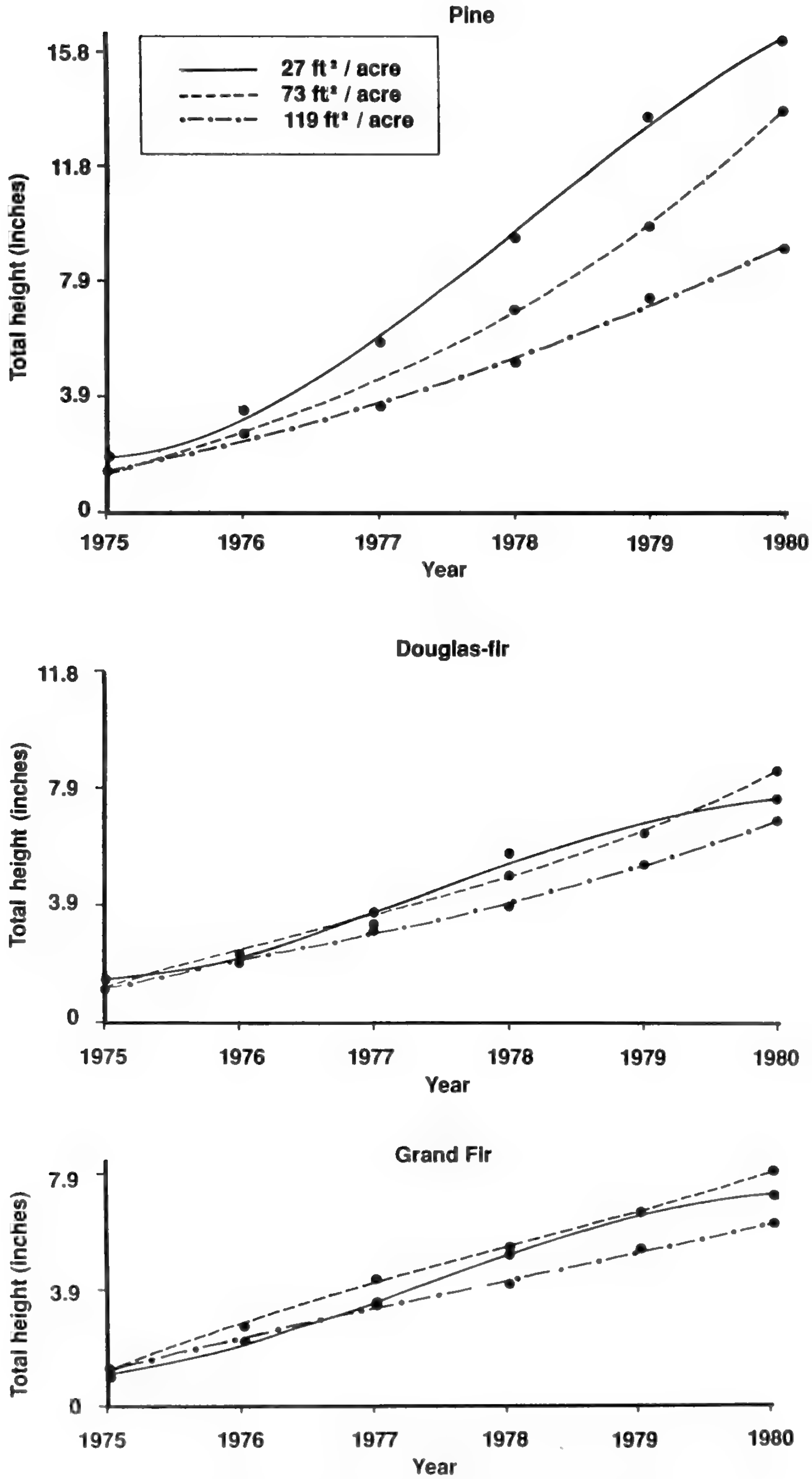

Figure 4—Average total height of tallest seedlings, by target density of residual overstory.

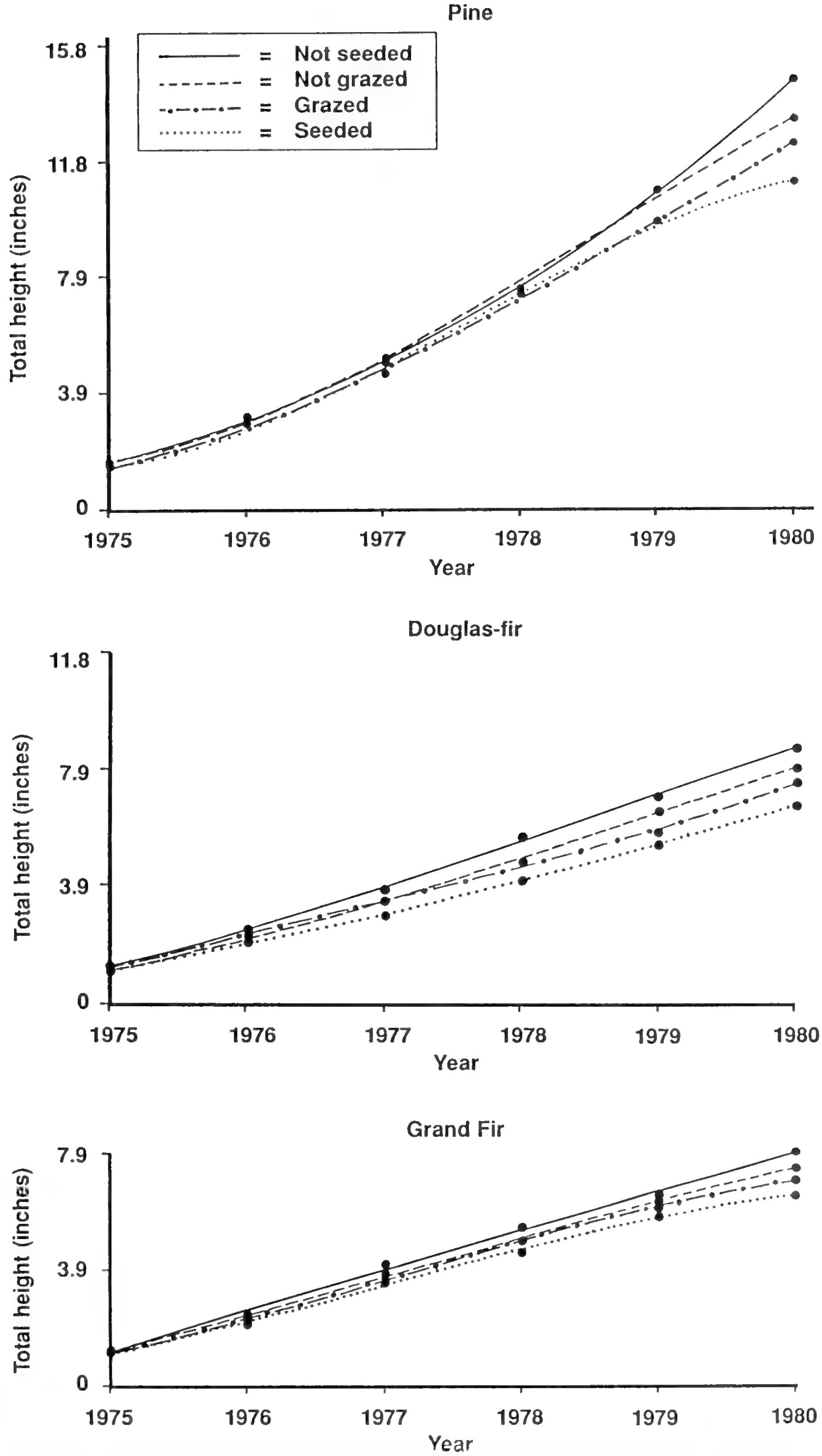

Figure 5—Average total height of tallest seedlings by grazing or seeding treatment. Data for seeded and unseeded treatments are mean values across all overstory densities and grazing treatments. Likewise, data for grazed and ungrazed treatments are mean values across all overstory densities and seeding treatments.

Seedbed Conditions and Regeneration

Because of generally complete slash removal from all plots, most quadrats contained only light amounts of litter and slash in 1975, and only minor changes occurred during the following 6 years (table 6). Plots at high density had fewer quadrats classified as mineral soil and more with medium and heavy amounts of litter because of less logging disturbance. Differences in amounts of grasses on the quadrats are primarily due to effects of the grass seeding and grazing treatments. In subplots where grass was seeded, more quadrats were covered in 1980 with medium and heavy amounts of grass and fewer with light amounts, especially on those subplots not grazed (table 7). Generally only light amounts of forbs and shrubs were present on the plots, with forbs increasing the most on low-density plots.

As expected, seedling density was highest on mineral soil seedbed and decreased as litter and slash became deeper (table 8). Although mineral soil provides the most favorable seedbed, many true fir seedlings did become established in seedbeds with light to medium litter and slash. Seedling numbers were greatly reduced only where intact, compact litter mats more than one-half inch thick were present. The large number of seedlings established in plots where mineral soil did not exceed 30-35 percent (table 6) shows that complete litter and slash removal is neither necessary nor desirable for adequate natural regeneration. All that is needed is to break up continuous layers of thick litter so that patches of mineral soil are small and well distributed over the area. This pattern is easily accomplished by logging disturbance and subsequent slash disposal operations. Keeping the soil litter and duff layer mainly intact has the benefits of reducing soil moisture loss and soil erosion and recycling nutrients present in litter and duff layers. Concern for soil compaction already exists, but keeping the soil in place is also a primary consideration in maintaining long-term site productivity. The importance of on-site retention of some well-distributed woody debris is being emphasized in light of recent research into the nutritional aspects of long-term productivity (Harvey and others 1987).

Competition from seeded grasses had little effect on numbers of new seedlings found annually or on their subsequent mortality. The average number of new seedlings found on seeded subplots from 1976 through 1980 was slightly greater than the number on unseeded subplots, and the mortality rates were similar (table 9). These differences were not statistically significant. Likewise, only small, nonsignificant differences existed between grazed and ungrazed subplots in annual new seedling numbers or mortality.

These results show that a light rate of grass seeding is compatible with establishment of tree seedlings, although height growth was reduced about 22 percent. Similar results were found by Kidd (1982) for planted Douglas-fir in Idaho and by Clark and McLean (1979) for lodgepole pine in British Columbia. Grass competition can, however, have negative effects on regeneration (Seidel 1979b, 1979c). Soil moisture is probably the most important factor influencing the effect of grass on seedling mortality. Except in extended years of drought with poor seed crops, light amounts of seeded grasses should not be detrimental to seedling establishment. Additional studies of several rates of grass seeding and grazing intensities after clearcutting and shelterwood cutting in various plant communities over several years would clarify the relations between grass competition, grazing, and tree regeneration.

Table 6—Percentage of quadrats classified as mineral soil or having light, medium, or heavy amounts of litter and slash by target density of residual overstory, subplot treatment, and year examined

Target density and subplot treatment[a]	Year examined	Mineral soil	Litter[b]			Slash[c]		
			Light	Medium	Heavy	Light	Medium	Heavy
			Percent					
27 square feet per acre:								
Not grazed, not seeded	1975	35	48	3	5	55	3	0
	1980	35	43	0	0	53	0	3
Not grazed, seeded	1975	48	33	5	5	40	3	0
	1980	30	45	5	5	28	10	0
Grazed, seeded	1975	25	63	10	0	60	0	5
	1980	25	55	10	0	58	0	5
Grazed, not seeded	1975	25	53	5	3	70	3	0
	1980	28	25	3	0	65	5	0
73 square feet per acre:								
Not grazed, not seeded	1975	33	50	8	3	60	0	0
	1980	13	63	8	3	60	15	5
Not grazed, seeded	1975	35	48	0	0	58	0	0
	1980	25	43	3	0	48	5	0
Grazed, seeded	1975	35	38	3	3	43	0	0
	1980	35	45	5	3	55	0	0
Grazed, not seeded	1975	30	45	5	0	63	3	0
	1980	25	65	3	0	68	10	0
119 square feet per acre:								
Not grazed, not seeded	1975	18	48	13	18	70	5	3
	1980	15	43	15	18	63	8	5
Not grazed, seeded	1975	15	55	13	8	63	8	8
	1980	15	40	23	13	60	10	5
Grazed, seeded	1975	28	40	10	10	48	3	5
	1980	3	55	3	13	75	18	5
Grazed, not seeded	1975	18	55	10	3	73	8	3
	1980	5	48	15	3	75	15	3

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.

[b] Amount of litter was classified as follows: light = uniform distribution of needles or small twigs over entire surface but mineral soil visible, or small patches of medium litter with mineral soil visible between patches; medium = uniform distribution of needles or small twigs to about 1/4-inch depth, or small patches of heavy litter with mineral soil visible between patches; heavy = needles and small twigs usually 1/4 to 3/4 inch deep but also deeper, generally in a compact mat, little or no mineral soil visible (Gordon 1970).

[c] Amount of slash was classified as follows: light = small pieces of slash covering less than 30 percent of surface; medium = any size slash covering 30-60 percent of surface; heavy = any size slash covering over 60 percent of surface (Gordon 1970).

Table 7—Percentage of quadrats having light, medium, or heavy amounts of understory vegetation by target density of residual overstory, subplot treatment, year examined, and vegetation type

		Understory vegetation type[b]								
		Grass and sedge			Forbs			Shrubs		
Target density and subplot treatment[a]	Year examined	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
		Percent								
27 square feet per acre:										
Not grazed, not seeded	1975	3	0	0	10	0	0	3	0	0
	1980	38	20	23	45	28	5	18	0	3
Not grazed, seeded	1975	68	15	0	3	0	0	0	0	0
	1980	10	35	55	20	0	0	0	0	0
Grazed, seeded	1975	65	10	0	3	0	0	3	0	0
	1980	23	40	28	38	0	0	0	0	0
Grazed, not seeded	1975	0	0	0	15	0	0	3	0	0
	1980	43	20	10	75	20	5	5	0	0
73 square feet per acre:										
Not grazed, not seeded	1975	0	0	0	12	8	0	0	0	0
	1980	33	0	0	53	3	0	3	0	0
Not grazed, seeded	1975	65	8	3	0	0	0	0	0	0
	1980	43	38	20	60	5	0	0	0	0
Grazed, seeded	1975	78	15	0	0	0	0	0	0	0
	1980	43	40	18	38	0	0	0	0	0
Grazed, not seeded	1975	3	0	0	13	0	0	0	0	0
	1980	18	0	0	63	5	0	5	0	0
119 square feet per acre:										
Not grazed, not seeded	1975	0	0	0	30	0	0	0	0	0
	1980	33	8	13	40	23	0	15	5	0
Not grazed, seeded	1975	45	13	3	0	0	0	0	0	0
	1980	17	13	43	23	3	0	3	0	0
Grazed, seeded	1975	55	3	0	15	3	0	0	0	0
	1980	55	13	0	55	10	0	0	0	0
Grazed, not seeded	1975	8	0	0	28	0	0	0	0	0
	1980	53	5	3	73	3	0	0	0	0

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.

[b] Amount of cover was classified as follows: light = 5-30 percent of quadrat covered; medium = 30-60 percent; heavy = more than 60 percent (Gordon 1970).

Table 8—Average number of seedlings per 1/2-milacre quadrat (all species) in 1975 by target density of residual overstory, and amounts of litter and slash

Target density and amount of slash[a] [b]	None	Litter[c] Light	Medium	Heavy
	Number[d]			
27 square feet per acre:				
None	9.6 (.6)	3.2 (.6)	0	0
Light	8.4 (1.7)	7.4 (.8)	4.7 (1.8)	1.8 (1.4)
Medium	0	1.5 (1.5)	0	3.0 (—)
Heavy	0	2.0 (2.0)	0	0
73 square feet per acre:				
None	25.7 (2.6)	19.5 (3.8)	0	0
Light	24.7 (2.5)	17.7 (1.6)	3.5 (1.0)	2.0 (1.0)
Medium	0	11.0 (—)	0	0
Heavy	0	0	0	0
119 square feet per acre:				
None	79.5 (14.9)	63.2 (17.8)	7.0 (—)	0
Light	44.9 (9.9)	37.6 (4.3)	11.1 (2.8)	6.2 (5.7)
Medium	0	12.7 (3.8)	8.4 (—)	3.0 (—)
Heavy	0	4.0 (—)	2.0 (1.2)	1.6 (—)

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after cutting. Actual densities after cutting were 38, 87, and 137 square feet per acre.
[b] Amount of slash was classified as follows: light = small pieces of slash covering less than 30 percent of surface; medium = any size slash covering 30-60 percent of surface; heavy = any size slash covering over 60 percent of surface (Gordon 1970).
[c] Amount of litter was classified as follows: light = uniform distribution of needles or small twigs over entire surface but mineral soil visible, or small patches of medium litter with mineral soil visible between patches; medium = uniform distribution of needles or small twigs to about 1/4-inch depth, or small patches heavy litter with mineral soil visible between patches; heavy = needles and small twigs usually 1/4 to 3/4 inch deep but also deeper, generally in a compact mat, little or no mineral soil visible (Gordon 1970).
[d] Standard errors are given in parentheses.

Table 9—Average number of new seedlings per acre (all species) from 1976 to 1980 and percentage mortality 1 year after origin by grazing or seeding treatment

	Not grazed		Grazed		Not seeded		Seeded		Mean	
Year of origin	Number[b]	Percent mortality	Number[b]	Percent mortality	Number[b]	Percent mortality	Number[b]	Percent mortality	Number[b]	Percent mortality
1976	1,317 (312)	10	900 (289)	5	975 (298)	10	1,109 (215)	6	1,109 (215)	8
1977	700 (231)	24	850 (187)	37	675 (201)	27	875 (116)	34	775 (100)	30
1978	242 (126)	18	517 (134)	28	409 (176)	18	350 (86)	27	380 (76)	23
1979	2,083 (489)	34	1,625 (349)	29	1,550 (308)	32	2,158 (402)	31	1,854 (333)	32
1980	743 (225)	—	1,025 (316)	—	1,075 (293)	—	684 (199)	—	880 (202)	—
Mean	1,015 (305)	21	983 (221)	25	937 (176)	21	1,062 (201)	25	—	—

[a] Data for grazed and not grazed data are mean values from all overstory densities and seeding treatments. Likewise, seeded and unseeded data are mean values from all overstory densities and grazing treatments.
[b] Standard errors are given in parentheses.

Overstory Mortality

Fifty-four overstory trees were lost during the 6-year study: 22 to windthrow and 32 apparently from exposure shock. Most mortality occurred in the low-density plots (26 trees); 14 trees were lost in the medium-density plots and 14 in high-density plots. Blowdown can be a serious problem in unmanaged old-growth stands such as these because the trees have not developed the windfirmness needed to resist increased wind stresses after partial cutting. The risk of blowdown can be reduced by leaving only dominant or codominant, fully crowned trees, which are the most windfirm and also the best seed producers (Gordon 1973), and by not using the shelterwood system on topography where the risk of blowdown is very high (Alexander 1964).

Soil Moisture

Statistical analyses of seasonal water depletion from evapotranspiration in the upper 36 inches of soil showed no significant differences resulting from grazing, seeding, or even density of the residual stand. This was true for both the 1st and the 5th year after logging. Trends in averages of soil moisture content indicated greater drawdown at the higher densities of residual overstory, but apparently replicate differences and perhaps other factors were great enough to affect statistical sensitivity. Recognizing this site-to-site variation is important in relation to expected results in broad-scale applications of given prescriptions. Because some sites are naturally "wetter" by virtue of deeper soils, occasional springs, or a more northerly aspect, or are drier because of opposite conditions, the manager can expect a range in results.

Conclusions

Natural regeneration was successfully established by use of the shelterwood system at all three overstory densities. Regeneration at the two highest densities (73 and 119 square feet of basal area per acre) was so abundant that plots were overstocked. More seedlings were established where mineral soil was exposed, but regeneration was also adequate on seedbeds where compact litter mats were broken up or where litter and duff did not exceed one-half inch in depth. Most of the regeneration resulted from the heavy seed crop that occurred immediately after the seed cut, but additional seedlings became established every year.

Seeded grasses sown at the rate of about 4.6 pounds per acre did not hinder the establishment of tree seedlings but did result in slower height growth. Thus, limited competition resulting from low seeding rates of grasses not forming sod means trees and grass can be compatible.

The grazing regime used in this study did not hamper seedling establishment nor did it significantly retard early height growth. These results are similar to those reported by Edgerton (1971), who found that limited cattle grazing had little effect on survival and growth of ponderosa pine planted in a mixed conifer clearcut. A carefully controlled grazing program can actually enhance tree seedling survival and growth by reducing competition from grasses and other understory vegetation (Krueger 1983). The same can be true with populations of wild ungulates, although control is more difficult. Edgerton (1987) reported that big game significantly altered conifer species composition and increased both stocking levels and height growth of regeneration in mixed conifer clearcuts in the Blue Mountains. Game indirectly influenced the tree crop by greatly altering the composition of successional vegetation, especially shrubs. Because the Blue Mountains of Oregon and Washington are well populated by big game, silviculturists need to recognize animal-plant interactions in assessing management strategies.

Determining the stand density suitable to leave after the seed cut in the shelterwood system depends on the amount of natural regeneration expected and the subsequent loss of established seedlings when the residual overstory is removed. Obviously, no more trees than necessary to obtain adequate regeneration should be left after the seed cut because avoiding mortality and damage to reproduction during overstory removal becomes more difficult as density of residual overstory increases. In this study, a residual overstory of about 30 to 40 square feet of basal area per acre appeared sufficient to provide adequate natural regeneration within a 5-year period. This finding agrees well with the results obtained from a survey of regeneration in partial cuts in grand fir/big huckleberry communities in the Blue Mountains (Seidel and Head 1983). To minimize losses of the residual overstory from windthrow, only the best dominant and codominant, fully crowned trees should be left after the seed cut. This objective can be more easily accomplished by marking the leave trees rather than the cut trees because the marker's attention is then focused on leaving the most desirable trees.

Proper multiple-use management of the timber and forage resource in the mixed conifer forests of eastern Oregon and Washington requires close cooperation between timber and range managers and users of the resource. Trees and grass can be compatible, provided timber and range managers coordinate planning to ensure that appropriate management practices are applied. The critical factors to consider are the (1) amount of residual overstory to leave when the shelterwood system is used; (2) timing, rate, and species composition of grasses, forbs, or shrubs to be sown; (3) timing of initiation, intensity, and duration of grazing by the selected classes of grazing animal(s); and (4) ability to predict response of native shrubs, herbs, and grasses. General guidelines for applying these factors in management prescriptions can be developed from studies such as this one. The properly balanced relation between trees and forage, however, undoubtedly varies with local soils, plant communities, topography, elevation, and microclimate. Therefore, site-specific prescriptions are required for optimum success, and involve the application of the coordinated talents of silviculturists, ecologists, range and wildlife managers, and user groups.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 mile = 1.61 kilometers
1 pound = 0.4536 kilogram
1 acre = 0.4047 hectare
1 square foot = 0.0929 square meter
1 square foot per acre = 0.2296 square meter per hectare
1 tree per acre = 2.47 trees per hectare

Literature Cited

Alexander, Robert R. 1964. Minimizing windfall around clear cuttings in spruce-fir forests. Forest Science. 10(2): 130-142.

Clark, M.B.; McLean A. 1979. Growth of lodgepole pine seedlings in competition with grass. Res. Note 86. Victoria, BC: Research Branch, Ministry of Forests, Province of British Columbia. 13 p.

Edgerton, Paul J. 1971. The effect of cattle and big game grazing on a ponderosa pine plantation. Res. Note PNW-172. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Edgerton, Paul J. 1987. Influence of ungulates on the development of the shrub understory of an upper slope mixed conifer forest. In: Provenza, Frederick D.; Flinders, Jerran T.; McArthur, E. Durant, comps. and eds. Symposium on plant-herbivore interactions: Proceedings; 1985 August 7-9; Snowbird, UT. Gen. Tech. Rep. INT-222. Odgen, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. p. 162-167.

Franklin, Jerry F.; Carkin, Richard; Booth, Jack. 1974. Seeding habits of upper-slope species. I. A 12-year record of cone production. Res. Note PNW-213. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Geist, J. Michael; Strickler, Gerald S. 1978. Physical and chemical properties of some Blue Mountain soils in northeast Oregon. Res. Pap. PNW-236. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 19 p.

Gordon, Donald T. 1970. Natural regeneration of white and red fir...influence of several factors. Res. Pap. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 32 p.

Gordon, Donald T. 1973. Damage from wind and other causes in mixed white fir-red fir stands adjacent to clearcutting. Res. Pap. PSW-90. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 22 p.

Hall, Frederick C. 1973. Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington. R-6 Area Guide 3-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 62 p.

Harvey, Alan E.; Jurgensen, Martin F.; Larsen, Michael J.; Graham, Russell T. 1987. Decaying organic materials and soil quality in the inland Northwest: a management opportunity. Gen. Tech. Rep. INT-225. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

Kidd, Frank. 1982. Reduced growth of Douglas-fir in a grass-seeded plantation. Forestry Tech. Pap. TP-82-2. Lewiston, ID: Potlatch Corporation. 4 p.

Krueger, W.C. 1983. Cattle grazing in managed forests. In: Roche, B.F., Jr.; Baumgartner, David M., comps. and eds. Symposium on forestland grazing: Proceedings; 1983 February 23-25; Spokane, WA. Pullman, WA: Washington State University; 1983: 71-73.

Schumacher, Francis X. 1926. Yield, stand, and volume tables for white fir in the California pine region. Station Bull. 407. Berkeley, CA: University of California College of Agriculture. 26 p.

Seidel, K.W. 1979a. Natural regeneration after shelterwood cutting in a grand fir-Shasta red fir stand in central Oregon. Res. Pap. PNW-259. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 23 p.

Seidel, K.W. 1979b. Regeneration in mixed conifer clearcuts in the Cascade Range and the Blue Mountains of eastern Oregon. Res. Pap. PNW-248. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 24 p.

Seidel, K.W. 1979c. Regeneration in mixed conifer shelterwood cuttings in the eastern Oregon Cascades. Res. Pap. PNW-264. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 p.

Seidel, K.W.; Cochran, P.H. 1981. Silviculture of mixed conifer forests in eastern Oregon and Washington. Gen. Tech. Rep. PNW-121. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 70 p.

Seidel, K.W.; Head, S. Conrade. 1983. Regeneration in mixed conifer partial cuttings in the Blue Mountains of Oregon and Washington. Res. Pap. PNW-310. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Williamson, Richard L. 1973. Results of shelterwood harvesting of Douglas-fir in the Cascades of western Oregon. Res. Pap. PNW-161. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Appendix

Table 10—Average number of seedlings present per acre (all ages) and percent stocking of 1/2-milacre quadrats from 1975 through 1980 by species, target density of residual overstory, and subplot treatment

	Target density of residual overstory[a]											
	27 square feet per acre				73 square feet per acre				119 square feet per acre			
Year examined, species, and percent stocking	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed seeded	Grazed, seeded	Grazed, not seeded
	Number of seedlings per acre[b]											
1975:												
Grand fir	10,950	9,050	12,500	14,850	40,900	30,050	37,250	35,950	118,900	82,650	51,750	36,850
	(1,281)	(1,174)	(1,717)	(1,881)	(5,225)	(2,996)	(5,851)	(3,926)	(21,384)	(15,784)	(11,757)	(5,650)
Douglas-fir	1,900	1,200	900	1,350	2,450	3,850	4,700	8,750	8,150	9,800	6,500	5,350
	(441)	(294)	(256)	(307)	(362)	(776)	(736)	(1,172)	(1,376)	(1,894)	(1,015)	(986)
Ponderosa and lodgepole pines	1,550	2,050	900	1,800	950	400	700	1,350	3,250	2,150	2,500	2,600
	(414)	(571)	(237)	(446)	(328)	(145)	(221)	(281)	(445)	(547)	(484)	(596)
Western larch	100	—	200	50	—	—	—	150	50	100	—	—
	(100)	(—)	(150)	(50)	(—)	(—)	(—)	(125)	(50)	(100)	(—)	(—)
Total	14,400	12,300	14,500	18,050	44,330	34,300	42,650	46,200	130,350	94,700	60,750	44,800
	(1,539)	(1,465)	(1,735)	(2,167)	(5,446)	(3,209)	(6,226)	(4,568)	(21,486)	(16,686)	(12,555)	(6,120)
	Percent per 1/2 milacre											
Stocking	93	85	98	100	98	100	100	100	100	100	95	100
	Number of seedlings per acre											
1976:												
Grand fir	7,450	5,850	6,000	9,150	34,250	26,650	27,800	30,450	108,950	68,100	34,700	29,450
	(1,038)	(1,034)	(1,057)	(1,394)	(5,105)	(2,864)	(4,302)	(3,403)	(20,763)	(14,058)	(7,089)	(4,432)
Douglas-fir	950	850	600	900	2,350	3,550	4,100	7,750	6,000	6,400	6,100	4,700
	(226)	(201)	(217)	(248)	(350)	(689)	(640)	(1,006)	(1,110)	(1,112)	(867)	(840)
Ponderosa and lodgepole pines	1,650	1,750	700	1,350	1,150	400	600	1,350	2,750	2,150	2,200	2,250
	(380)	(560)	(197)	(402)	(392)	(147)	(205)	(307)	(378)	(550)	(404)	(546)

Table 10—Average number of seedlings present per acre (all ages) and percent stocking of 1/2 milacre quadrats from 1975 through 1980 by species, target density of residual overstory, and subplot treatment (continued)

	Target density of residual overstory[a]											
	27 square feet per acre				73 square feet per acre				119 square feet per acre			
Year examined, species, and percent stocking	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed seeded	Grazed, seeded	Grazed, not seeded
Western larch	100 (100)	— (—)	200 (150)	50 (50)	— (—)	— (—)	— (—)	150 (125)	100 (50)	100 (100)	— (—)	— (—)
Total	10,150 (1,235)	8,450 (1,352)	7,600 (1,085)	11,450 (1,689)	37,750 (5,348)	30,600 (3,071)	32,500 (4,685)	39,700 (3,958)	117,200 (20,777)	76,750 (14,839)	43,000 (7,800)	36,400 (4,762)
	Percent per 1/2 milacre											
Stocking	90	75	85	90	93	98	100	100	100	100	98	98
	Number of seedlings per acre											
1977:												
Grand fir	5,250 (903)	4,250 (982)	4,600 (861)	6,350 (1,057)	30,150 (4,809)	22,850 (2,560)	25,600 (4,395)	28,550 (3,342)	89,250 (17,140)	51,750 (10,581)	29,950 (5,780)	22,850 (3,310)
Douglas-fir	650 (192)	650 (181)	550 (175)	800 (211)	2,300 (340)	3,350 (674)	3,800 (629)	7,900 (1,066)	5,300 (1,079)	5,300 (1,038)	5,350 (733)	3,800 (620)
Ponderosa and lodgepole pines	1,350 (361)	1,400 (448)	450 (168)	950 (336)	1,200 (410)	450 (147)	550 (202)	1,400 (306)	1,750 (357)	1,700 (476)	2,400 (447)	1,850 (434)
Western larch	100 (100)	— (—)	200 (150)	50 (50)	— (—)	— (—)	— (—)	200 (125)	550 (156)	100 (100)	— (—)	— (—)
Total	7,350 (1,057)	6,300 (1,235)	5,800 (960)	8,150 (1,336)	33,650 (5,048)	26,650 (2,760)	29,950 (4,762)	38,050 (3,986)	96,850 (17,142)	58,850 (10,990)	37,700 (6,307)	28,500 (3,631)
	Percent per 1/2 milacre											
Stocking	83	68	73	78	90	98	98	98	100	98	98	100
	Number of seedlings per acre											
1978:												
Grand fir	3,550 (653)	3,050 (640)	3,500 (778)	5,450 (960)	28,300 (4,676)	20,100 (2,061)	22,350 (4,314)	25,300 (3,090)	70,300 (13,086)	42,200 (7,729)	29,500 (5,510)	22,250 (3,208)
Douglas-fir	350 (135)	500 (156)	250 (128)	500 (168)	2,100 (368)	3,150 (619)	3,450 (585)	7,650 (964)	4,600 (844)	4,450 (940)	4,850 (726)	3,700 (625)
Ponderosa and lodgepole pines	1,350 (349)	1,400 (448)	400 (122)	750 (300)	1,100 (365)	450 (147)	550 (202)	1,450 (304)	1,650 (322)	1,750 (476)	2,300 (448)	1,900 (449)
Western larch	100 (100)	— (—)	150 (100)	150 (100)	100 (80)	— (—)	200 (175)	150 (125)	600 (160)	250 (120)	50 (50)	50 (50)
Total	5,350 (801)	4,950 (923)	4,300 (831)	6,850 (1,192)	31,600 (4,969)	23,700 (2,267)	26,550 (4,654)	34,550 (3,642)	77,150 (13,138)	48,650 (8,142)	36,700 (6,021)	27,900 (3,633)
	Percent per 1/2 milacre											
Stocking	78	65	68	78	90	98	98	98	98	98	98	98
	Number of seedlings per acre											
1979:												
Grand fir	2,900 (679)	1,700 (352)	2,700 (533)	3,900 (659)	27,400 (4,289)	18,500 (1,952)	20,600 (3,697)	24,650 (2,770)	60,750 (11,172)	41,200 (7,384)	25,600 (4,585)	20,100 (2,748)

Table 10—Average number of seedlings present per acre (all ages) and percent stocking of 1/2 milacre quadrats from 1975 through 1980 by species, target density of residual overstory, and subplot treatment (continued)

	Target density of residual overstory[a]											
	27 square feet per acre				73 square feet per acre				119 square feet per acre			
Year examined, species, and percent stocking	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed seeded	Grazed, seeded	Grazed, not seeded
Douglas-fir	350	550	200	400	2,450	3,450	3,550	7,800	5,400	7,500	5,150	4,350
	(141)	(160)	(125)	(141)	(431)	(636)	(515)	(1,014)	(841)	(1,244)	(734)	(669)
Ponderosa and lodgepole pines	1,350	1,100	450	650	1,250	500	1,050	1,700	1,550	1,800	2,550	1,700
	(348)	(304)	(147)	(279)	(370)	(152)	(312)	(376)	(308)	(419)	(465)	(428)
Western larch	100	—	50	150	150	50	200	400	600	300	—	100
	(100)	(—)	(50)	(100)	(100)	(50)	(175)	(153)	(207)	(128)	(—)	(100)
Total	4,700	3,350	3,400	5,100	31,250	22,500	25,400	34,550	68,300	50,800	33,300	26,250
	(841)	(582)	(547)	(856)	(4,622)	(2,115)	(4,095)	(3,462)	(11,262)	(7,945)	(5,119)	(3,352)
	Percent per 1/2 milacre											
Stocking	65	60	65	73	90	95	98	98	100	98	95	98
	Number of seedlings per acre											
1980:												
Grand fir	2,700	1,600	2,600	3,100	26,150	18,150	20,650	22,150	52,400	34,150	23,150	16,550
	(683)	(344)	(517)	(601)	(3,873)	(1,911)	(3,700)	(2,476)	(9,864)	(5,618)	(4,023)	(1,988)
Douglas-fir	300	550	150	400	2,600	3,200	3,500	7,800	6,200	6,150	4,900	3,900
	(137)	(160)	(115)	(141)	(479)	(609)	(509)	(1,014)	(1,211)	(1,089)	(661)	(563)
Ponderosa and lodgepole pines	1,250	1,050	450	650	1,000	500	750	1,650	1,600	1,900	2,400	1,700
	(350)	(297)	(147)	(279)	(354)	(152)	(288)	(380)	(323)	(422)	(413)	(428)
Western larch	100	—	50	100	350	50	200	350	650	200	—	50
	(100)	(—)	(50)	(100)	(200)	(50)	(175)	(143)	(214)	(115)	(—)	(50)
Total	4,350	3,200	3,250	4,250	30,100	21,900	25,100	31,950	60,850	42,400	30,450	22,200
	(802)	(576)	(523)	(719)	(4,332)	(2,089)	(4,003)	(3,012)	(9,763)	(7,322)	(5,088)	(3,143)
	Percent per 1/2 milacre											
Stocking	63	60	65	68	90	98	98	98	100	98	93	95

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per acre.

[b] Standard errors are given in parentheses.

Table 11—Average total height of tallest seedings per 1/2-milacre quadrant from 1975 through 1980 by species, target density of residual overstory, and subplot treatment

	Target density of residual overstory[a]											
	27 square feet per acre				73 square feet per acre				119 square feet per acre			
Year examined, species, and percent stocking	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed seeded	Grazed, seeded	Grazed, not seeded
	Inches[b]											
1975:												
Grand fir	0.8	0.9	1.1	1.3	1.4	1.1	1.0	1.2	1.5	1.1	1.1	1.2
	(.05)	(.06)	(.07)	(.08)	(.09)	(.06)	(.06)	(.04)	(.06)	(.04)	(.04)	(.06)
Douglas-fir	1.2	0.9	1.1	1.1	1.4	1.1	1.0	1.1	1.5	1.1	1.1	1.3
	(.40)	(.13)	(.09)	(.08)	(.09)	(.06)	(.06)	(.04)	(.06)	(.04)	(.04)	(.06)
Ponderosa and lodgepole pines	1.9	1.8	1.5	1.8	1.5	1.7	1.1	1.4	1.6	1.3	1.3	1.5
	(.13)	(.16)	(.11)	(.16)	(.12)	(.14)	(.11)	(.09)	(.08)	(.08)	(.08)	(.11)
1976:												
Grand fir	2.5	1.9	1.9	2.2	2.7	2.7	2.7	2.8	2.8	2.1	2.0	2.2
	(.38)	(.15)	(.11)	(.15)	(.18)	(.11)	(.13)	(.16)	(.13)	(.13)	(.11)	(.11)
Douglas-fir	2.8	1.9	2.1	2.6	2.6	2.2	2.4	2.3	2.4	1.9	2.1	2.1
	(.33)	(.17)	(.13)	(.22)	(.19)	(.12)	(.11)	(.12)	(.15)	(.14)	(.08)	(.12)
Ponderosa and lodgepole pines	4.1	3.7	3.1	3.3	2.8	2.6	2.9	2.9	3.4	2.5	2.5	2.7
	(.37)	(.26)	(.28)	(.35)	(.32)	(.31)	(.24)	(.24)	(.26)	(.19)	(.16)	(.21)
1977:												
Grand fir	3.5	3.1	3.4	3.8	4.4	4.2	4.4	4.7	4.6	3.4	2.9	3.6
	(.22)	(.23)	(.27)	(.31)	(.26)	(.20)	(.22)	(.25)	(.29)	(.20)	(.17)	(.21)
Douglas-fir	4.8	2.4	2.4	3.5	4.0	3.0	3.8	4.0	3.5	2.8	2.9	3.3
	(1.7)	(.40)	(.35)	(.52)	(.31)	(.19)	(.20)	(.22)	(.28)	(.21)	(.17)	(.24)
Ponderosa and lodgepole pines	6.0	6.8	5.6	4.8	4.7	4.1	4.6	5.0	4.7	3.7	2.9	3.6
	(.91)	(.79)	(.83)	(.87)	(.67)	(.67)	(1.2)	(.43)	(.63)	(.43)	(.31)	(.47)
1978:												
Grand fir	5.5	4.6	4.8	5.9	5.4	5.2	5.4	5.7	5.3	3.7	3.2	4.3
	(.36)	(.38)	(.40)	(.43)	(.33)	(.35)	(.26)	(.33)	(.33)	(.20)	(.21)	(.28)
Douglas-fir	7.1	4.3	4.7	6.5	5.5	4.5	4.5	5.1	5.0	3.3	3.6	3.9
	(1.3)	(.63)	(.91)	(1.7)	(.47)	(.47)	(.28)	(.27)	(.43)	(.20)	(.24)	(.33)
Ponderosa and lodgepole pines	8.2	11.9	9.1	8.8	7.8	5.7	6.1	8.4	7.1	4.8	4.0	4.8
	(1.3)	(1.7)	(.94)	(1.4)	(1.4)	(1.0)	(1.6)	(1.1)	(1.2)	(.59)	(.51)	(.67)
1979:												
Grand fir	6.3	6.2	7.1	6.7	6.8	6.1	6.3	7.0	7.2	5.2	4.0	5.1
	(.71)	(.55)	(.47)	(.67)	(.51)	(.31)	(.31)	(.43)	(.55)	(.35)	(.24)	(.35)
Douglas-fir	8.0	5.8	4.6	7.4	7.8	5.5	6.1	6.6	6.5	5.2	4.8	4.7
	(1.6)	(1.0)	(1.9)	(1.4)	(.71)	(.55)	(.47)	(.40)	(.55)	(.40)	(.35)	(.35)
Ponderosa and lodgepole pines	12.2	15.9	14.4	12.1	11.5	7.8	6.9	12.9	9.8	7.7	5.4	6.7
	(1.5)	(2.9)	(2.9)	(2.7)	(2.1)	(1.4)	(1.0)	(1.6)	(1.4)	(.79)	(.71)	(1.1)

Table 11—Average total height of tallest seedings per 1/2-milacre quadrant from 1975 through 1980 by species, target density of residual overstory, and subplot treatment (continued)

	Target density of residual overstory[a]											
	27 square feet per acre				73 square feet per acre				119 square feet per acre			
Year examined, species, and percent stocking	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed, seeded	Grazed, seeded	Grazed, not seeded	Not grazed, not seeded	Not grazed seeded	Grazed, seeded	Grazed, not seeded
	Inches[b]											
1980:												
Grand fir	7.3	6.5	6.1	8.8	8.7	7.4	7.8	8.4	8.4	5.8	4.9	6.0
	(.79)	(1.0)	(.79)	(1.0)	(.79)	(.55)	(.55)	(.83)	(1.2)	(.51)	(.43)	(.59)
Douglas-fir	9.3	7.1	5.1	9.1	9.9	6.6	8.9	8.7	8.9	6.4	6.1	6.1
	(.59)	(2.4)	(2.5)	(1.6)	(1.4)	(.83)	(1.2)	(.75)	(1.1)	(.87)	(.67)	(.79)
Ponderosa and lodgepole pines	19.2	14.8	15.3	15.5	14.4	10.4	12.0	15.9	12.7	7.8	6.3	9.8
	(2.6)	(3.1)	(4.5)	(4.0)	(3.9)	(3.4)	(5.0)	(3.2)	(2.0)	(.91)	(1.3)	(1.6)

[a] Target density is the average basal area of the residual overstory on whole plots that was desired after shelterwood cutting. Actual densities after cutting were 33, 87, and 137 square feet per plot.

[b] Standard errors are given in parentheses.

Seidel, K.W.; Geist, J. Michael; Strickler, Gerald S. 1990. The influence of cattle grazing and grass seeding on coniferous regeneration after shelterwood cutting in eastern Oregon. Res. Pap. PNW-RP-417. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p.

Natural regeneration was abundant, regardless of grazing and grass seeding treatments, after shelterwood cutting to three overstory densities (27, 73, and 119 square feet of basal area per acre) in mixed conifer stands in the Starkey Experimental Forest and Range in eastern Oregon. After 6 years, the number of tree seedlings ranged from about 3,800 per acre on the low-density plots to 39,000 per acre on the high-density plots and consisted of about 84 percent grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.); 10 percent Douglas-fir (*Pseudotsuga menziesii* var. glauca (Beissn.) Franco); and 6 percent ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), and western larch (*Larix occidentalis* Nutt.). Neither grazing nor seeded grasses decreased seedling establishment, but the grass did retard seedling height growth. The greatest number of seedlings were found on mineral soil seedbeds, but adequate stocking occurred where light to medium amounts of litter and slash were present. A residual overstory of about 30-40 square feet of basal area per acre appears adequate to provide natural regeneration within a 5-year period. Seeding 4 to 5 pounds of less competitive grasses and grazing up to 60 percent of current year's growth were compatible with tree seedling establishment.

Keywords: Shelterwood cutting method, regeneration (natural), grass, forage, grazing, grand fir, *Abies grandis*, Douglas-fir, *Pseudotsuga menziesii* var. *glauca*, Oregon (eastern).

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